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THE INFLUENCE OF ETHYL ALCOHOL
INGESTION ON A TARGET TASK DURING
SUSTAINED $+G_z$ CENTRIFUGATION

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13. ABSTRACT

Eight adults, 7 males and 1 female, drank orange juice mixed with 95% ethyl alcohol (0; 0.5; 1; 2; or 3 oz.). Alcohol content of the juice was not revealed to the subject. One hour afterwards, blood alcohol (B/A) was determined by breath analysis and then the subject was exposed to a series of 7 sec. tasks during 45-sec. accelerations (+G_z) (Group 1: 1, 3, 4, and 5 G; Group 2: 1, 3, 5, and 6 G). During each acceleration, a subject was randomly presented 6 tracking tasks. Performance was quantified as the time (sec.) required to "hit" an electronic target. The effects of G and/or alcohol consumption and B/A upon task performance were considered as the change from 1 G with no alcohol. The combination of the higher alcohol - G levels resulted in a potentiated reduction in performance. 9.8% reduction per G in performance per 0.10 B/A was evident in the range from 1 through 6 G.

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Influence of Ethyl Alcohol Ingestion on a Target Task During Sustained +G_z Centrifugation

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BURTON, R. R., and J. L. JAGGARS. *Influence of ethyl alcohol ingestion on a target task during sustained +G_z centrifugation.* Aerospace Med. 45 (3):290-296, 1974.

Eight adults (7 males and 1 female) drank orange juice mixed with 95% ethyl alcohol (0; 0.5; 1; 2; or 3 oz). Alcohol content of the juice was not revealed to the subject. One hour afterwards, percent blood alcohol (B/A) was determined by breath analysis and then the subject was exposed to a series of 7-s tasks during 45-s accelerations (+G_z). (Group 1: 1, 3, 4, and 5G; Group 2: 1, 2, 3, 5, and 6 G). During each acceleration, a subject was randomly presented six tracking tasks. Performance was quantified as the time in seconds (s) required to "hit" an electronic target. The acute effects of G and/or alcohol consumption and B/A upon task performance were considered as the change from 1 G with no alcohol. The combination of the higher alcohol and G levels resulted in a potentiated reduction in performance. A 9.9% reduction per G in performance per 0.10 B/A was evident in the range from 1 through 6 G independent of the decrease in performance at various accelerative levels with a B/A of 0.

ALCOHOL APPEARS to be a contributing factor in 10% to 40% of general aviation accidents (3,8,9,11,22). Also, evidence suggests that some causal relationships between alcohol and military aviation accidents exist, although at greatly reduced incidence (7).

Military flight frequently produces accelerative forces (+G_z) which significantly alter the ambient gravitational environment for aircrew. Sadoff and Dolkas (21), Rogers *et al.* (17), and Zuidema *et al.* (27), reported significant reductions in task performance as G increased. Alcohol consumption also is known to adversely affect performance (1,2,6,13). However, when alcohol is combined with other drugs or environmental stressors,

human performance usually is reduced synergistically (14,16,18,24,26).

Little information is available regarding the effects of alcohol combined with sustained G. Browne (4) observed that alcohol decreased blackout tolerance and increased the incidence of nausea and disorientation occasionally associated with centrifugation—human performance, however, was not measured in this experiment. Considering the lack of knowledge in this area and the possibility of a synergistic decrease in human capability during exposure to increased G after alcohol ingestion, the following experiments were performed and the results are reported herein.

MATERIALS AND METHODS

Experimental Design: Eight adult subjects (7 males and 1 female) with prior acceleration (centrifugation) experience were allowed several opportunities to gain experience in using our target task at several sustained (45 s) acceleration levels (+6 G_z maximum). Each subject gained a satisfactory level of self-evaluated competence; *viz.*, the level of ability where each person subjectively considered further experience would not increase proficiency. Standard USAF CSU-12P anti-G suits were worn during acceleration exposures and the subject was allowed to perform the M-1 straining maneuver as necessary to prevent peripheral light loss (PLL). A maximum level of 45-s exposure to either 5 or 6 G was chosen by the subject as the highest +G_z level where he or she felt "comfortable" while performing the task. Consequently, two experimental groups (four subjects/group) were formed, each using one of the following acceleration (in-order) profiles: (a) 1 G (in the centrifuge gondola, but not moving—static test); 3 G; 4 G; and 5 G; or (b) 1 G (static test); 3 G; 5 G; and 6 G (Table I). Accelerations were produced by the USAFSAM human centrifuge using safety procedures stipulated elsewhere (15).

Task performance during acceleration was evaluated twice each week using random alcohol ingestion levels (Table I). The volume of 95% ethyl alcohol for each subject was measured and then mixed with 1 pint of fresh orange juice. The alcohol content of the orange juice was unknown to the subject. The juice-alcohol

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The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 80-33.

mixture was swallowed within 15 minutes. One hour following alcohol ingestion and after the G-suit was donned, the percent blood alcohol (B/A) level (grams of alcohol/100 ml of blood) was determined using breath analysis methods* (23)—the B/A was unknown to the subject. At this time, the subject was seated and restrained with a harness in an aircraft seat inside the centrifuge gondola and exposed to the appropriate (a) or (b) series of 45-s acceleration runs with 2- to 3-min rests between each acceleration exposure. During each acceleration exposure target-task abilities, ECG, and heart rate were monitored using a Mark 200 Brush recorder, and simultaneously taped on a Model 4742 Sangamo recorder for later computer analysis.

Three additional acceleration task performances were conducted in which neither alcohol nor orange juice was consumed. The first of these occurred at the beginning, the second in the middle, and the third as the final experiment (Table I). These differed from the no-alcohol control performance in that the subject had not drunk any liquid prior to acceleration exposure, thereby realizing that alcohol was not being administered. Using these learning control tasks, it was possible to (a) recognize task performance proficiency changes which conceivably might have occurred as the subject gained more experience in performing the tasks during the course of the experiment and (b) quantify effects resulting from acceleration per se independent of alcohol consumption.

Target Task: We devised the target task and details will become available as a local technical report. The task uses two 12-in oscilloscopes, one located in the centrifuge gondola for viewing by the subject and the other in the centrifuge control room operated by the monitor. The target appears on both oscilloscope screens as a "lighted +". The target first is presented electronically on the monitor's screen whereupon he has the option of initial target location on the scope periphery; eight positions are available about the circular screen. The actuating of the task is the release of the target by the monitor which presents the target on the subject's screen for the first time. The target is electronically driven by the subject in the centrifuge by moving an aircraft-control stick between the subject's legs—the gondola's interior configuration is the mockup of a fighter aircraft (15). The subject attempts to center the target on his screen, upon which is painted a gunsight. Superimposing the gunsight and target positions on the scope and simultaneously pressing the "firing" button located on the control stick results in a "hit" and the target disappears from the screen only to reappear again at some location—again selected by the monitor—on the screen's periphery at the beginning of the second task. Each task is limited to 7 s and a series of six tasks require a total of 45 s—0.5 s is required for each task presentation. The occurrence of a hit within the 7 s

TABLE I. ETHYL ALCOHOL (95%) ORAL INGESTION SCHEDULE FOR EACH SUBJECT IN OUNCES.

Subject	Semi-weekly experimental sessions								
	1*	2	3	4	5*	6	7	8	9*
PW†	0	0**	1	2	0	0.5	3	1.5	0
TC†	0	0.5	2	3	0	1	1.5	0**	0
GT†	0	1	0.5	3	0	2	0**	1.5	0
RD†	0	2	3	0**	0	1	0.5	0.8	0
JH	0	3	0**	0.5	0	2	1	0.5	0
RK	0	0**	1	2	0	0.5	3	1.5	0
Jr	0	1	3	0.5	0	2	0**	1.5	0
AW	0	2	1	0**	0	3	0.5	1.5	0
Mean dose#	(1.2	1.4	1.4)	= 1.3+	(1.5	1.2	1.1)	= 1.3+	

* Target-task learning controls.

** Drank orange juice only.

† Acceleration profile "b" (note text).

Mean alcohol dose (oz) per subject for each semi-weekly session.

+ Overall mean alcohol dose (oz) per subject for each phase of the experiment.

allotted time per task and the disappearance of the target result in a wait by the subject until the next task is presented always at 7.5 s intervals. The firing time ("ammunition") was unlimited during the task; however, the subject was cautioned against excessive ammunition expenditure. The location of the target on the scope, three different performance times, and shots fired per task were electronically monitored, taped, and later computer analyzed. Thus, it was possible to quantify several psychomotor responses by the subject during target display (Tables IV and V).

RESULTS

Subjective response: Each subject, at the completion of the day's accelerative exposures was asked the following personal opinion questions: (a) Was any alcohol in the orange juice you consumed? (b) Approximately how much? (c) Did the alcohol affect your acceleration tolerance (increase or decrease)? and (d) Did alcohol affect your task performance (increase or decrease)? Acceleration tolerance was considered by the subject as the relative ease or difficulty in preventing PLL during the higher +G_x levels by using the M-1 straining maneuvers. An analysis of this questionnaire compared with the alcohol consumption level is found in Table II.

The greater the alcohol concentration of the orange juice, the more readily was the alcohol recognizable yet, even at 1 oz., one subject did not realize the alcohol content of the liquid. Interestingly, this same subject previously had recognized alcohol in a weaker solution of 0.5 oz alcohol orange juice. Three subjects believed alcohol to be present in nonalcoholic orange juice. One such subject thought the "alcohol" reduced his acceleration tolerance whereas another subject considered his overall task performance helped by "alcoholic drink."

Self-evaluation of task performance was quite accurate, with the majority of subjects rating their task abilities low after 2 oz (B/A range of 0.06-0.10) of alcohol. Drinking 3 oz of alcohol convinced all of the

*Standard "breath-analysis" techniques as described by Stephenson Corp., Red Bank, NJ, were employed using a Model 900 "Breathalyzer."

TABLE II. SUBJECTIVE OBSERVATIONS EXPRESSED AS PERCENTAGES OF THE TOTAL EXPERIMENTAL POPULATION REGARDING ACCELERATION TOLERANCE, TASK PERFORMANCE, AND ABILITY TO RECOGNIZE ALCOHOLIC CONTENTS OF THE ORANGE JUICE COMPARED WITH ALCOHOL DOSE AND BLOOD ALCOHOL LEVELS.

Alcohol dosage; oz (B/A range)**	N	Alcohol recognized (%)	Acceleration tolerance (%)			Task performance (%)		
			Improved	No change	Reduced	Improved	No change	Reduced
0 (0)	8	37*	0	67	33	33	67	0
0.5 (.01-.03)	9	67	0	67	33	0	83	17
1 (.02-.05)	9	89	38	50	12	25	53	12
2 (0.06-0.10)	12	92	18	55	27	0	27	73
3 (above 0.10)	9	100	56	22	22	0	0	100

N = number of observations per alcohol dose group.

* 3 of 8 subjects thought some alcohol was in the no-alcohol orange juice (control drink).

** B/A = % blood alcohol range of subjects 1 hr following alcohol ingestion as determined by breath analysis.

subjects that their task performance was reduced. On the other hand, alcohol subjectively affected acceleration tolerance quite differently in that following 3 oz of alcohol consumption, 56% of the subjects considered their ability to keep vision during +G_z required less effort and the usual discomfort of the pressurized G suit was diminished. One subject (3 oz) had difficulty maintaining vision during the 5 G exposure because of an unsatisfactory M-1 effort.

Other general comments on the subjective effect of alcohol appeared to involve problems in orientation associated with the higher 2- and 3-oz doses; viz., (a) increased "tumbling" sensation at the termination of a 5- or 6-G run, (b) increased nausea, and (c) feeling of being in a continuous "dive" at 5 G. The nausea feeling verifies the earlier findings of Browne (4).

Other interesting complaints at the 2- and 3-oz doses were the appearance of the target at 5 and 6 G to seven of the eight subjects. Four complained that the target became "blurry" whereas three explained that the target "fluttered" up and down, giving a "jerky motion-picture" effect. In these three subjects, a definite vertical nystagmus was observed via the centrifuge TV monitor.

Heart Rate: Data from only the 1-, 3-, and 5-G exposures were analyzed, since both groups of subjects were exposed to these acceleration levels. Statistically significant effects (analysis of variance) were found

between heart rate and alcohol consumption ($p < 0.01$) and between heart rate and acceleration ($p < 0.001$).

Heart rates at 1 G and prior to acceleration were statistically elevated following alcohol ingestion—an alcohol effect was present and quantitatively similar at all dosage levels. Consequently, the alcohol effect on mean heart rate during the 45-s exposures was considered irrespective of dose and is shown in Table III relative to acceleration effects. An elevation in heart rate correlated with alcohol ingestion is found at 1, 3, and 5 G_z although its relative (percentage) effect upon the total heart rate change is greatly reduced at +5 G_z.

The acceleration effect on heart rate following alcohol ingestion is specific for acceleration and quite independent of pre-acceleration (baseline) heart rate; e.g., the heart rate at 1 G, with alcohol was elevated to 110 which is approximately the mean heart rate at +3 G_z without alcohol, yet exposures of individuals to +3 G_z

TABLE III. MEAN HEART RATE FOR +G_z EXPOSURES WITH AND WITHOUT ALCOHOL INGESTION. THE RELATIVE ALCOHOL AND ACCELERATION EFFECTS (%) AT 1, 3, AND +5 G_z ARE SHOWN IN FINAL LINES.

G	1	3	5
No alcohol	98.2	113.3	142.7
All doses of alcohol	110.0	131.3	155.0
Alcohol effect %	12.0	15.9	8.6
G effect %	0	15.4	45.3

effect % = [(Experimental - Control)/Control] × 100

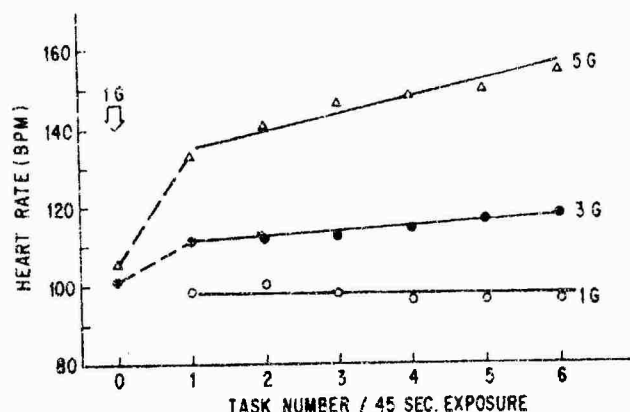


Fig. 1. Heart rate increases during acceleration exposure in the absence of alcohol—each task number represents 7.5 s duration. The arrow denotes heart rate at 1 G prior to acceleration onset. Task No. 1 is the mean heart rate during the first 7.5 s exposure after the appropriate G level is reached.

TABLE IV. EFFECT OF ACCELERATION ON FOUR TARGET-TASK INDICES IN ABSENCE OF ALCOHOL (ANALYSIS OF VARIANCE).

Acceleration	Total firing time/task (seconds)	Total time target on screen/task (seconds)	Reaction time (seconds)	Shots fired/task (number)
1	.248	3.54	.411	1.3
3	.456	4.29	.348	2.0
5	.489	4.40	.313	2.0
p <	0.001	0.001	0.001	0.001

TABLE V. EFFECT OF ALCOHOL CONSUMPTION ON FOUR TARGET-TASK INDICES AT 1 G (ANALYSIS OF VARIANCE).

Alcohol Dose (oz)	Total firing time/task (seconds)	Total time target on screen/task (seconds)	Reaction time (seconds)	Shots fired/task (number)
0	.248	3.540	.411	1.3
0.5	.240	3.573	.431	1.4
1.0	.241	3.703	.422	1.3
2.0	.236	3.363	.438	1.4
3.0	.299	4.246	.472	1.5
p <	0.05	0.001	N.S.	N.S.

N.S. = not statistically significant; $p > 0.05$.

with the elevated alcoholic heart rate resulted in a further increase in heart rate to 131.3.

Although mean acceleration heart rates are shown in Table III, a time effect (duration) at +3 G_z was statistically determined for seven subjects and is shown for nonalcohol heart rate in Fig. 1—qualitatively similar acceleration responses also were noted following alcohol ingestion. The initial abrupt increase in heart rate at acceleration onset (dashed lines) is followed by a continuing increase in heart rate during +G_z—the higher the G, the greater the effect. The heart rate response is apparently independent of task anxiety since it was not found in subjects performing the task at 1 G (Fig. 1).

Task performance: This was the first time that this particular target-task has been used experimentally. Consequently, the useable indices were unknown until data analysis was attempted. The following obvious measurements were evaluated statistically using an analysis of variance: (a) total firing time per task, (b) total time target on screen per task, (c) reaction time—time interval between target appearance on screen and the first stick movement, and (d) number shots fired per task.

The task results were evaluated in two stages: (a) learning controls were analyzed to determine the effects of acceleration per se and to determine if a significant change in task skill had occurred during the experimental period of 5 weeks, and (b) analysis of those portions of the task where various levels of alcohol had been ingested.

Acceleration-Learning effects: All four of the indices in the learning control group were a function of G-level as shown in Table IV. Several measurements of task

performance—(a) total firing time, (b) total time target was on the screen, and (c) shots fired—indicated a reduction in target tracking ability as the G level increased. Interestingly however, the subjects apparently became more alert during G exposure as shown by a significant reduction in mean reaction times at both 3 and 5 G.

With regard to learning, two of the four indices—"reaction time" and "total time target on screen"—were statistically shortened as the experiment progressed. The reaction time at all G levels went from a mean of 0.395 s at learning control 1 to a mean of 0.340 s at the end of the experiments. Total time target on screen per task likewise was reduced statistically during the course of the experiment by 0.594 s. However, since the alcohol doses were randomly distributed over the duration of the experiment, data sensitive to learning were not re-evaluated for this learning effect.

Alcohol effect: The alcohol effect at 1 G upon the above four target-task indices is shown in Table V. Alcohol ingestion significantly increased total firing time per task and total time target appeared on the screen—effects similar to those resulting from increased G (Table IV). Unlike acceleration effects, however, reaction time was increased with alcohol consumption, although not statistically significant, and shots fired per task were not significantly altered.

Combined acceleration-alcohol effect: The combined effects of alcohol ingestion and G exposure on task performance were considered in detail using the index "total time target was on the screen per task." We believe that this index combines several task performance assess-

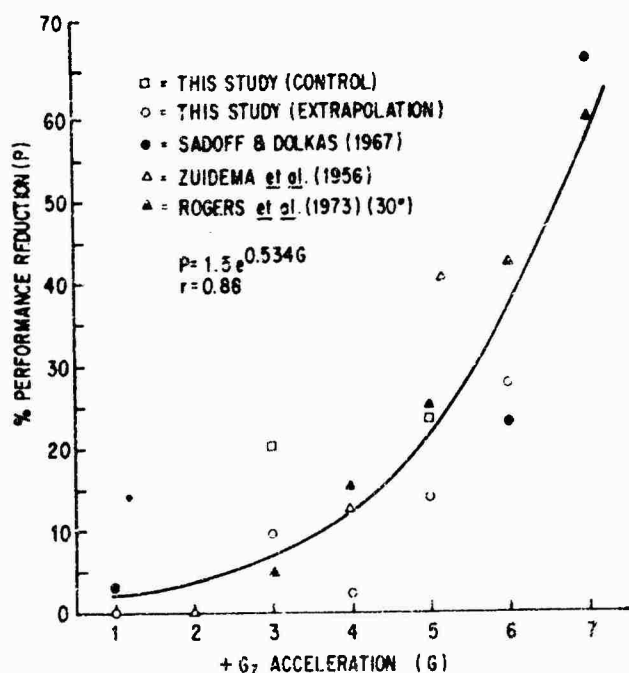


Fig. 2. Percent reduction in performance (P) as a function of acceleration (G) as determined in this investigation in the absence of ingested alcohol and compared with previous studies.

TABLE VI. PERCENTAGE REDUCTION IN TASK PERFORMANCE# AS A FUNCTION OF VARIOUS DOSES OF ALCOHOL AND/OR LEVEL OF ACCELERATION (G) EXPOSURE COMPARED WITH PREDICTED VALUES.†

+G _z	Alcohol (oz)					Source
	0.0	0.5	1.0	2.0	3.0	
1	0	4	5	1	21	observed
3	22	14†	20†	21	62*	observed
		26	27	23	43	predicted‡
5	26	20†	37	72*	79*	observed
		30	31	27	47	predicted‡

† = less than summation; * = synergistic increase; ‡ = predicted reduction if Δ task performance was a function of the summation of alcohol and G effects.

Task performance defined in text as "total time target appeared on screen"; % reduction = [Time (control; 1 G; 0 alcohol) - Time (>1 G; >0 alcohol)] / Time (Control) \times 100.

TABLE VII. VALUES FOR THE EQUATION ($P = a + bA$) CONSIDERING PERCENT REDUCTION IN TASK PERFORMANCE (P) AS A FUNCTION OF PERCENT BLOOD ALCOHOL (A) AT EACH G-LEVEL.

+G _z	1	3	4	5	6
a	0	12	4.5	17	30
b	102	249	424	483	616
n*	47	47	20	46	21
r†	0.26	0.44	0.68	0.60	0.72
p# <	0.10	0.01	0.01	0.01	0.01

* n = number of pairs of variables per G.

† r = correlation coefficient.

p < = statistical probability by chance occurrence.

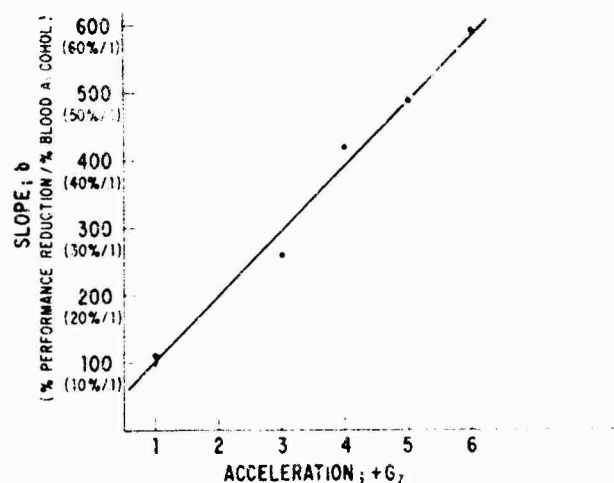


Fig. 3. Relationship of percent reduction in task performance per percent blood alcohol concentration (b) with acceleration (G) exposure independent of G effects without alcohol.

ments into a single quantity: (a) reaction times and (b) several measurements of accuracy. The sensitivity of this index as a learning indicator was borne out in the learning control portion of this experiment. Also, it was the only index that was affected statistically similarly either by alcohol or acceleration (Tables IV and V). Henceforth in the text, the term "task performance" is synonymous with "total time target is on screen per task." The time per selected task was considered as a percent change from 1 G (no alcohol) controls and compared with effects of both increased G and alcohol consumption. These data also are compared with the "predicted percentage reduction" if change in task performance had been a simple additive function of the alcohol effect and G effect (Table VI). Interestingly, reduction in task performance is seldom a simple summation of these two effects. This only occurs at 3 G with 2 oz of alcohol and 5 G with 1 oz of alcohol. In general, less G and less alcohol together results in a less-than-additive effect and more G together with more alcohol causes potentiation—a synergistic reduction in task performance.

The individual reduction in task performance was considered with percent blood alcohol level for each G tested using regression analysis. A quantitatively different rectilinear equation was determined for each G level:

$$P = a + bA \quad (\text{Eq. 1})$$

Where:

P = % reduction in task performance, and

A = % blood alcohol

Values for the intercept ("a") and slope ("b") and correlation coefficient ("r" value) for each G-level are shown in Table VII.

The intercepts ("a") of these equations denote the percent task reduction independent of blood alcohol—G effect only. These are compared with data obtained at the 3- and 5-G levels in the learning control portion of

this study and from other task-performance studies (Fig. 2) (17), (20), (27). Our results—denoted by squares and open circles—suggest agreement as to the percentage of performance reduction which occurs during +G_x exposure in the absence of alcohol. The values from Rogers et al. (17) are from subjects seated with a 30° back-angle tilt which should not differ significantly from the other data in Fig. 2 obtained using the more conventional 13° seat angle (5). Our mathematical description of all available performance reduction (P) values relative to +G_x acceleration (G) appears to be exponential:

$$P = 1.5e^{0.534G} \quad (Eq. 2)$$

$$r = 0.88; p < 0.01$$

In the 1- to 5-G range the effect of acceleration on reduction in performance appears to be relatively moderate; however, as G increases and the subject is required to strain and perform the exhausting M-1 maneuvers to maintain vision, performance rapidly deteriorates.

The slopes ("b") of Eq. 1 found in Table VII quantify the percent reduction in task performance as a function of blood alcohol percent. The slope "steepens" with an increase in each G level, suggesting a combination of G and blood alcohol effects upon task performance. This relationship between percent task reduction/percent blood alcohol—slopes "b" of rectilinear equations (Eq. 1) derived for each subject (n = 30)—with increasing G was considered using rectilinear regression analysis:

$$b = 4 + 99G \quad (Eq. 3)$$

$$r = 0.67; p < 0.01; n = 30$$

This relationship is plotted in Fig. 3. Each slope "b" represents the percent in reduction per concentration of blood alcohol as shown along the ordinate; viz., 400 = 40% reduction in performance in a person with a blood alcohol concentration of 0.1%, which is a level frequently considered to be excessive for operating a motor vehicle.

The G slope (99), therefore, of Eq. 3 indicates that a 9.9% reduction occurs with each G increase in acceleration in those persons with a blood alcohol concentration of 0.1% independent of the decrease in performance found at various accelerative levels with a B/A of 0 ("a" of Eq. 1).

DISCUSSION

Visual problems regarding the target task were reported by seven of the eight subjects at 5 and 6 G with blood alcohols of 0.09 and higher. Included in these seven subjects were three who complained of the target "fluttering up and down" giving a "jerky motion picture" effect. Vertical nystagmus was observed in these subjects during the G exposure via the television monitor. This nystagmus response appears to correspond with Phase I of the "positional alcohol nystagmus" phenomenon (PAN I) recently reviewed by Ryback and Dowd (20). This impairment of vestibular function appears about 30 min after alcohol ingestion and lasts about 3 to 4 hours.

The other four subjects also had visual problems at the higher G levels; however, they described the target

as "blurry" and the occurrence of vertical nystagmus was not observed. The physiological basis for blurred vision associated with alcohol appears to be associated with a muscle imbalance which occurs prior to double vision (diplopia). This phenomenon also appears to be exaggerated by increased accelerative forces.

Exposures to high G during military aeronautics are of short duration. Consequently, methods used to test performance during sustained high G must meet the essential requirement that the duration of the test be short lived. Only those reaction-type tests may be used, therefore, which eliminate the more complex and, probably, more sensitive tests based on memory. It has been hypothesized that psychomotor performance tests of short duration are not appropriate for studying the acute effects of alcohol since it appears that man can compensate for alcohol over brief spans of time (19). Frequently, therefore, the effects of alcohol on performance are determined using psychomotor testing over an extended period of time. Rutenfranz and Jansen (19) used 30 min tests and Fluech *et al.* (10) tested for a 1-hr session. Their performance degradation percentage was on the order of 10 times those reported in this study.

On the other hand, shorter-lived tasks—the 10-min "Kugeltest" (12) and controlled aircraft maneuvers with experienced and inexperienced pilots (2)—have been used at 1 G to estimate performance decrements associated with alcohol ingestion and piloting aircraft. The results of these tests of shorter duration were similar and suggested performance decrements in the order of 20% with a B/A of 0.10.

Our tracking task—very simple and lasting only 45 s—identified reductions in task performance at 1 G of 21% associated with alcohol ingestion of 3 oz and a mean B/A of 0.12 (Table VI). However, we were unable to detect reductions in task performance at 1 G in the lesser alcohol range, as was done by others using more-sophisticated testing methods (2,12).

Interestingly, our subject's performance appeared to be quite sensitive to acceleration per se; e.g., 3 G resulted in approximately the same percent reduction as found at 1 G in performance (22%) after ingesting 3 oz of alcohol (21%—note Table VI). Of course, as noted earlier, the combination of 3 oz of alcohol at 3 G results in a potentiated 62% reduction in task performance.

It is appropriated to note that Billings *et al.* (2) observed specific pilot errors which they termed as "major" and "catastrophic" with a percent blood alcohol of 0.04—a level where they found only a 2% reduction in overall task performance. In our study, the combination of 3 G and 3 oz of alcohol produced an overall reduction in mean task performance of 79% (Table VI).

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